

CERTIFICATE OF TRANSLATION

I, TAKESHI OSHIO, patent attorney of Fifteenth Floor, Crystal Tower, 1-2-27 Shiromi, Chuo-ku, Osaka 540-6015, Japan HEREBY CERTIFY that I am acquainted with the English and Japanese languages and that the attached English translation is a true English translation of what it purports to be, a translation of Japanese Patent Application No. 7-206367 on 11 August, 1995 in the name of SHARP KABUSHIKI KAISHA.

Dated this 10th day of October 2006

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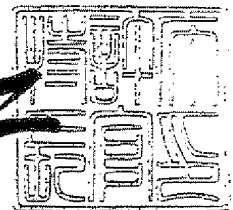
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(Translation)

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[Title of the Invention]	TRANSMISSION TYPE LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR FABRICATING THE SAME
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(Translation)

[Name of the Document] SPECIFICATION

[Title of the Invention] Transmission type liquid crystal display device and method for fabricating the same

[Claims]

[Claim 1] A transmission type liquid crystal display device having switching elements each arranged near a crossing of a gate signal line and a data signal line, a gate electrode of the switching element being connected to the gate signal line, an electrode of the switching element other than the gate electrode being connected to the data signal line, and the other electrode of the switching element being connected to a pixel electrode,

wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the gate signal lines, and the data signal lines, and

the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film.

[Claim 2] A transmission type liquid crystal display device including gate signal lines and data signal lines formed to cross each other and switching elements each arranged near a crossing of the gate signal line and the data signal line, a gate electrode of the switching element being connected to the gate signal line, an electrode of the switching element other than the gate electrode being connected to the data signal

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line, and the other electrode of the switching element other than the gate electrode being connected to a pixel electrode via a connecting electrode, so that a data signal is supplied to the pixel electrode via the switching element to realize liquid crystal display,

wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the gate signal lines, the data signal lines, and the connecting lines,

the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film so that at least a portion of each of the pixel electrodes overlaps at least one of at least the gate signal line and the data signal line, and

the connecting electrode and the pixel electrode are connected with each other via a contact hole formed through the interlayer insulating film.

[Claim 3] A transmission type liquid crystal display device according to claim 1 or 2, wherein the interlayer insulating film is made of a photosensitive acrylic resin.

[Claim 4] A transmission type liquid crystal display device according to any of claims 1 to 3, wherein the interlayer insulating film is made of a resin which is made transparent by optical or chemical decoloring treatment.

[Claim 5] A transmission type liquid crystal display device according to claim 1 or 2, wherein the pixel electrode overlaps at least one of the data signal line and the gate signal line overlap by 1  $\mu$ m or more in



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a line width direction.

[Claim 6] A transmission type liquid crystal display device according to any of claims 1 to 4, wherein the thickness of the interlayer insulating film is 2.0  $\mu\text{m}$  or more.

[Claim 7] A transmission type liquid crystal display device according to claim 2, wherein the connecting electrode is formed of a transparent conductive film.

[Claim 8] A transmission type liquid crystal display device according to claim 2, wherein the contact hole is formed above a storage capacitor line constituting each pixel.

[Claim 9] A transmission type liquid crystal display device according to claim 2 or 8, wherein a metal nitride layer is formed below the contact hole to connect the connecting electrode and the pixel electrode.

[Claim 10] A transmission type liquid crystal display device according to claim 1 or 2, wherein a capacitance ratio represented by expression (1):

$$\text{Capacitance ratio} = C_{sd} / (C_{sd} + C_{ls} + C_s) \quad \dots(1)$$

is 10% or less, wherein  $C_{sd}$  denotes a capacitance value between the pixel electrode and the data signal line,  $C_{ls}$  denotes a capacitance value of a liquid crystal portion corresponding to each pixel in an intermediate display state, and  $C_s$  denotes a capacitance value of the storage capacitor of each pixel.

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[Claim 11] A transmission type liquid crystal display device according to any of claims 1, 2, 5, 6, and 10, wherein the shape of the pixel electrode is rectangular with a side parallel to the source signal line being longer than a side parallel to the gate signal line.

[Claim 12] A transmission type liquid crystal display device according to claim 1 or 2, further comprising a display driving circuit for supplying a data signal of which polarity is inverted every gate signal line to the data signal line, to be supplied to the pixel electrode via the switching element.

[Claim 13] A method for fabricating a transmission type liquid crystal display device, comprising the steps of:

forming a plurality of switching elements in a matrix on a substrate, forming a gate signal line connected to a gate electrode of each of the switching elements and a data signal line connected to an electrode of the switching element other than the gate electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the gate electrode;

forming an organic thin film with high transparency above the switching elements, the gate signal lines, the source signal lines, and the connecting lines by spin coating and patterning the organic thin film to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and

forming pixel electrodes made of transparent

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conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the gate signal line and the data signal line.

[Claim 14] A method for fabricating a transparent type liquid crystal display device according to claim 13, wherein the patterning of the interlayer insulating film is conducted by light exposure and alkaline development or by an etching process after the formation of a photoresist on the interlayer insulating film.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a transmission type liquid crystal display device which includes switching elements such as thin film transistors (hereinafter, referred to as "TFTs"), and a method for fabricating the same.

[0002]

[Prior Art]

Figure 9 is a circuit diagram of a conventional transmission type liquid crystal display device provided with an active matrix substrate.

[0003]

Referring to Figure 9, the active matrix substrate includes a plurality of pixel electrodes 1 arranged in a matrix and TFTs 2 used as switching elements connected to the respective pixel electrodes 1. Gate

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electrodes of the TFTs 2 are connected to gate signal lines 3, so that gate signals can be input into the gate electrodes to control the driving of the TFTs 2. Source electrodes of the TFTs 2 are connected to source signal lines 4, so that data (display) signals can be input into the corresponding pixel electrodes 1 via the TFTs 2 when the TFTs 2 are being driven. The gate signal lines 3 and the source signal lines 4 run along peripheries of the pixel electrodes 1 arranged in a matrix to cross each other. Drain electrodes of the TFTs 2 are connected to the respective pixel electrodes 1 and storage capacitors 5. Counter electrodes of the storage capacitors 5 are connected to common lines 6.

[0004]

Figure 10 is a sectional view of a one-TFT portion of the active matrix substrate of the conventional liquid crystal display device.

[0005]

Referring to Figure 10, a gate electrode 12 connected to the gate signal line 3 shown in Figure 9 is formed on a transparent insulating substrate 11. A gate insulating film 13 is formed covering the gate electrode. A semiconductor layer 14 is formed on the gate insulating film so as to overlap the gate electrode 12 via the gate insulating film, and a channel protection layer 15 is formed on the center of the semiconductor layer.  $n^+$ -Si layers as a source electrode 16a and a drain electrode 16b are formed covering the end portions of the channel protection layer 15 and portions of the semiconductor layer 14, so that they are separated from each other at the top of the channel protection layer 15.

A metal layer 17a which is to be the source signal line 4 shown in Figure 9 is formed to overlap the source electrode 16a as one of the n<sup>+</sup>-Si layers. A metal layer 17b is formed to overlap the drain electrode 16b as the other n<sup>+</sup>-Si layer so as to connect the drain electrode 16b and the pixel electrode 1. An interlayer insulating film 18 is formed covering the TFT 2, the gate signal line 3, and the source signal line 4.

[0006]

A transparent conductive film is formed on the interlayer insulating film 18 to constitute the pixel electrode 1. The transparent conductive film is connected to the metal layer 17b which is in contact with the drain electrode 16b of the TFT 2 via a contact hole 19 formed through the interlayer insulating film 18.

[0007]

Thus, since the interlayer insulating film 18 is formed between the signal lines 3 and 4 and the transparent conductive film which is to be the pixel electrode 1, it is possible to overlap the pixel electrode 1 with the lines 3 and 4. Such a structure is disclosed in Japanese Laid-Open Patent Publication No. 58-172685, for example. With this structure, the aperture ratio improves and, since the electric field generated by the signal lines 3 and 4 is shielded, disturbance in the orientation of liquid crystal can be minimized.

[0008]

Conventionally, the interlayer insulating film 18 is formed by depositing an inorganic material such as silicon nitride (SiN) to a thickness of about 5000

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angstrom by CVD.

[0009]

[Problems to be Solved by the Invention]

By forming the interlayer insulating film 18 between the pixel electrodes 1 and the layer of the gate signal lines 3 and the source signal lines 4 as in the above-described conventional liquid crystal display device, it is possible to overlap each pixel electrode 1 with the signal lines 3 and 4, increasing the aperture ratio of the resultant liquid crystal display device and minimizing the disturbance in the orientation of liquid crystal. In such an overlap structure of the signal lines 3 and 4 and the pixel electrode 1, the capacitances between the pixel electrode 1 and the lines 3 and 4 increase. In particular, when an inorganic film made of silicon nitride and the like is used, the dielectric constant of such a material is as high as 8 and, since the film is formed by CVD, the thickness of the resultant film is as small as about 5000 angstrom. With such a thin interlayer insulating film, the capacitances between the pixel electrode 1 and the signal lines 3 and 4 are large. This causes the following problems (1) and (2). Incidentally, in order to obtain a thicker inorganic film made of silicon nitride and the like, an undesirably long time is required in the aspect of the fabrication process.

[0010]

(1) When the pixel electrode 1 overlaps the source signal line 4, the capacitance between the pixel electrode 1 and the source signal line 4 becomes large. This increases the signal transmittance, and thus a data

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signal held in the pixel electrode 1 during a holding period fluctuates depending on the potential thereof. As a result, the effective voltage applied to the liquid crystal in the pixel varies, causing, in particular, vertical crosstalk toward a pixel adjacent in the vertical direction in the actual display.

[0011]

In order to reduce the influence of the capacitance between the pixel electrode 1 and the source signal line 4 appearing on the display, Japanese Laid-Open Patent Publication No. 6-230422 proposes a driving method where the polarity of a data signal to be supplied to the pixels is inverted every source signal line. This driving method is effective for a black-and-white display panel where the displays adjacent pixels are highly correlated with each other. However, it is not effective for a color display panel for normal notebook type personal computers and the like where pixel electrodes are arranged in a vertical stripe shape (in color display, a square pixel is divided into three vertically long rectangular picture elements representing R, G, and B, forming a vertical stripe shape). The display color of pixels connected to one source signal line 4 is different from that of pixels connected to an adjacent source signal line. Accordingly, the above method of inverting the polarity of the data signal every source signal line is not effective in reducing vertical crosstalk for the general color display, though it is effective for the black-and-white display.

[0012]

(2) When the pixel electrode 1 overlaps the gate

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signal line 3 for driving the pixel, the capacitance between the pixel electrode 1 and the gate line 3 becomes large, increasing the feedthrough of the write voltage to the pixel due to a switching signal for controlling the TFT 2.

[0013]

In order to solve the above problems, an objective of the present invention is to provide a transmission type liquid crystal display device where pixel electrodes overlap respective signal lines to improve the aperture ratio of the liquid crystal display, minimize disturbance in the orientation of liquid crystal, and the influence of the capacitance between the pixel electrodes and the signal lines appearing on the display, such as crosstalk, can be reduced to achieve a good display, and a method for fabricating the same.

[0014]

[Means for Solving the Problems]

The transmission type liquid crystal display device according to the present invention has switching elements each arranged near a crossing of a gate signal line and a data signal line, a gate electrode of the switching element being connected to the gate signal line, an electrode of the switching element other than the gate electrode being connected to the data signal line, and the other electrode of the switching element being connected to a pixel electrode, wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the gate signal lines, and the data signal lines, and the pixel electrodes made of a transparent



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conductive film are formed above the interlayer insulating film, whereby the above objective is attained.

[0015]

Alternatively, the transmission type liquid crystal display device according to the present invention includes gate signal lines and data signal lines formed on a transparent insulating substrate to cross each other and switching elements each arranged near a crossing of the gate signal line and the data signal line, a gate electrode of the switching element being connected to the gate signal line, an electrode of the switching element other than the gate electrode being connected to the data signal line, and the other electrode of the switching element other than the gate electrode being connected to a pixel electrode via a connecting electrode, so that a data signal is supplied to the pixel electrode via the switching element to realize liquid crystal display, wherein an interlayer insulating film made of an organic thin film with high transparency is formed above the switching elements, the gate signal lines, the data signal lines, and the connecting lines, the pixel electrodes made of a transparent conductive film are formed above the interlayer insulating film so that at least a portion of each of the pixel electrodes overlaps at least one of at least the gate signal line and the data signal line, and the connecting electrode and the pixel electrode are connected with each other via a contact hole formed through the interlayer insulating film, whereby the above objective is attained.

[0016]

The interlayer insulating film is preferably made

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of a photosensitive acrylic resin.

[0017]

The interlayer insulating film may be made of a resin which is made transparent by optical or chemical decoloring treatment.

[0018]

The pixel electrode may overlap at least one of the source signal line and the gate signal line overlap by 1  $\mu\text{m}$  or more in a line width direction.

[0019]

The thickness of the interlayer insulating film is desirably 2.0  $\mu\text{m}$  or more.

[0020]

The connecting electrode is desirably formed of a transparent conductive film.

[0021]

The contact hole is desirably formed above a storage capacitor line constituting each pixel.

[0022]

A metal nitride layer is desirably formed below the contact hole to connect the connecting electrode and the pixel electrode.

[0023]

The capacitance ratio represented by expression (1) above is desirably 10% or less.

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[0024]

The pixel electrodes may be arranged in a vertical strip shape, and the shape of each pixel electrode may be rectangular with a side parallel to the source signal line being longer than a side parallel to the gate signal line.

[0025]

The method for driving the transmission type liquid crystal display device includes inverting the polarity of a data signal supplied from the source signal line every gate signal line, whereby the above objective can be easily attained.

[0026]

The method for fabricating a transmission type liquid crystal display device includes the steps of: forming a plurality of switching elements in a matrix on a substrate, forming a gate signal line connected to a gate electrode of each of the switching elements and a data signal line connected to an electrode of the switching element other than the gate electrode so as to cross each other, and forming a connecting electrode made of a transparent electrode connected to the other electrode of the switching element other than the gate electrode; forming an organic thin film with high transparency above the switching elements, the gate signal lines, the source signal lines, and the connecting lines by spin coating and patterning the organic thin film to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes made of transparent conductive films on the interlayer

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insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps at least one of at least the gate signal line and the data signal line, whereby the above objective is attained.

[0027]

Preferably, in the method for fabricating a transparent type liquid crystal display device, the patterning of the interlayer insulating film is conducted by light exposure and alkaline development or by an etching process after the formation of a photoresist on the interlayer insulating film.

[0028]

More specifically, the method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a transparent insulating substrate, forming a gate signal line connected to a gate electrode of each of the switching elements and a data signal line connected to an electrode of the switching element other than the gate electrode so as to cross each other, and forming a connecting electrode made of a transparent conductive film connected to the other electrode of the switching element other than the gate electrode; forming a photosensitive resin above the switching elements, the gate signal lines, the source signal lines, and the connecting lines by spin coating and patterning by light exposure and alkaline development to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming

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pixel electrodes made of transparent conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps the switching element, the gate signal line, the source signal line, and the connecting electrode.

[0029]

Alternatively, more specifically, the method for fabricating a transmission type liquid crystal display device according to the present invention includes the steps of: forming a plurality of switching elements in a matrix on a transparent insulating substrate, forming a gate signal line connected to a gate electrode of each of the switching elements and a data signal line connected to an electrode of the switching element other than the gate electrode so as to cross each other, and forming a connecting electrode made of a transparent conductive film connected to the other electrode of the switching element other than the gate electrode; forming an organic thin film above the switching elements, the gate signal lines, the source signal lines, and the connecting lines, forming a photoresist on the organic thin film, and patterning by an etching process to form an interlayer insulating film and forming contact holes through the interlayer insulating film to reach the connecting electrodes; and forming pixel electrodes made of transparent conductive films on the interlayer insulating film and inside the contact holes so that at least a portion of each of the pixel electrodes overlaps the switching elements, the gate signal lines, the source signal lines, and the connecting electrode.

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[0030]

The function of the liquid crystal display device with the above configuration will be described.

[0031]

According to the present invention, the interlayer insulating film is formed above the switching elements, the gate signal lines, and the source signal lines, and the pixel electrodes are formed on the interlayer insulating film, so that each of the pixel electrode is connected to the other electrode of the TFT via the connecting electrode and the contact hole formed through the interlayer insulating film. With the existence of the interlayer insulating film, the pixel electrode can be formed to overlap the corresponding signal lines. This improves the aperture ratio and minimizes disturbances in the orientation of the liquid crystal. Since the interlayer insulating film is composed of an organic thin film made of a photosensitive acrylic resin and the like, a high-quality film with a smaller dielectric constant and higher transparency can be obtained with good productivity, compared with an inorganic thin film such as silicon nitride film conventionally used. This makes it possible to increase the thickness of the film. Thus, the capacitances between the pixel electrode and the signal lines can be reduced, and the signal transmittance is suppressed. As a result, the influence such as crosstalk on the display caused by the capacitance component between the pixel electrode and the signal lines can be reduced, providing better display.

[0032]

The pixel electrode is connected to the other electrode of the switching element other than the gate electrode via the connecting electrode. Therefore, a connecting portion such as the contact hole formed through the interlayer insulating film can be easily formed even when the TFT is small.

## [0033]

The interlayer insulating film is formed by applying a photosensitive organic material such as an acrylic resin to the substrate by spin coating and patterning by light exposure and alkaline development to obtain an organic thin film with a thickness of several micrometers with high productivity. This can also be obtained by forming the organic thin film by deposition, forming a photoresist on the organic thin film, and patterning the organic thin film in an etching process.

## [0034]

When the resin as the material for the interlayer insulating film is colored, the resin can be made transparent by an optical or chemical decoloring treatment after the patterning.

## [0035]

The aperture ratio can be maximized by overlapping the pixel electrode with the signal lines by 1  $\mu\text{m}$  or more. With this overlap, the processing precision of the pixel electrode with respect to the lines may not be so high, because as long as the pixel electrode overlaps the lines, light leakage is blocked by the lines even when the processing precision is not so high.

[0036]

When the thickness of the interlayer insulating film is 2.0  $\mu\text{m}$  or more, the capacitance between the signal lines and the pixel electrode is sufficiently small and the signal transmittance is small even if the overlap of the pixel electrode with the signal lines is 1  $\mu\text{m}$  or more. This further reduces the influence of the capacitance component on the display, such as crosstalk, providing better display.

[0037]

The aperture ratio further improves by using a transparent conductive film for the connecting electrode for connecting the other electrode of the TFT to the pixel electrode.

[0038]

By forming the contact hole above the light-shading storage capacitor line, light leakage due to disturbances in the orientation of the liquid crystal occurs in the light-shading portion, not the aperture portion. This prevents the contrast from lowering.

[0039]

By forming the metal nitride layer below the contact hole formed through the interlayer insulating film, the adhesion between the interlayer insulating film and the underlying layer increases.

[0040]

By reducing the capacitance ratio represented by expression (1) above to 10% or less, good display can be obtained since the capacitance between the pixel elec-



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trode and the source electrode is sufficiently reduced.

[0041]

By applying the present invention, the influence of the capacitance component on the display, such as vertical crosstalk, can be eliminated to obtain good display even when each pixel electrode is of a rectangular shape with the side thereof parallel to the source signal line being longer than the side thereof parallel to the gate signal line.

[0042]

The influence of the capacitance between the source signal line and the pixel electrode can be further reduced by inverting the polarity of a data signal supplied from the source signal line every gate signal line.

[0043]

[Embodiments of the Invention]

Hereinbelow, the embodiments of the invention will be described.

[0044]

(Embodiment 1)

Figure 1 is a plan view of a one-pixel portion of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 1 according to the present invention.

[0045]

Referring to Figure 1, the active matrix substrate includes a plurality of pixel electrodes 21 ar-

ranged in a matrix. Gate signal lines 22 and source signal lines 23 run surround the peripheries of the pixel electrodes 21 so as to cross each other. The peripheries of each pixel electrode 21 overlap the gate signal lines 22 and the source signal lines 23. A TFT 24 acting as a switching element connected to the corresponding pixel electrode 21 is formed at a crossing of the gate signal line 22 and the source signal line 23. A gate electrode of the TFT 24 is connected to the gate signal line 22 so that a signal can be input into the gate electrode to control the driving of the TFT 24. A source electrode of the TFT 24 is connected to the source signal line 23 so that a data signal can be input into the source electrode of the TFT 24. A drain electrode of the TFT 24 is connected to the pixel electrode 21 via a connecting electrode 25 and a contact hole 26. The drain electrode is also connected to an electrode 25a of a storage capacitor via the connecting electrode 25. The other electrode 27 of the storage capacitor is connected to a common line.

[0046]

Figure 2 is a sectional view of the active matrix substrate of the transparent type liquid crystal display device taken along line A-A' of Figure 1.

[0047]

Referring to Figure 2, a gate electrode 32 connected to the gate signal line 22 shown in Figure 1 is formed on a transparent insulating substrate 31. A gate insulating film 33 is formed covering the gate electrode. A semiconductor layer 34 is formed on the gate insulating film so as to overlap the gate electrode 32 via the gate

insulating film, and a channel protection layer 35 is formed on the center of the semiconductor layer.  $n^+$ -Si layers as a source electrode 36a and a drain electrode 36b are formed covering the end portions of the channel protection layer 35 and portions of the semiconductor layer 34, so that they are separated from each other by a portion of the channel protection layer 35. A transparent conductive film 37c and a metal layer 37b which are to be the double-layer source signal line 23 are formed to overlap the source electrode 36a as one of the  $n^+$ -Si layers. A transparent conductive film 37a' and a metal layer 37b' are formed to overlap the drain electrode 36b as the other  $n^+$ -Si layer. The transparent conductive film 37a' extends to connect the drain electrode 36b and the pixel electrode 21 and also serves as the connecting electrode 25 which is connected to the electrode 25a of the storage capacitor. An interlayer insulating film 38 is formed covering the TFT 24, the gate line 22, the source line 23, and the connecting electrode 25.

[0048]

A transparent conductive film is formed on the interlayer insulating film 38 to constitute the pixel electrode 21. The pixel electrode is connected to the drain electrode 36b of the TFT 24 via the contact hole 26 formed through the interlayer insulating film 38 and the transparent conductive film 37d' which is the connecting electrode 25.

[0049]

The active matrix substrate in Embodiment 1 with the above structure is fabricated as follows.

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[0050]

First, the gate electrode 32, the gate insulating film 33, the semiconductor layer 34, the channel protection layer 35, and the n<sup>+</sup>-Si layers as the source electrode 36a and the drain electrode 36b are sequentially formed in this order on the transparent insulating substrate 31 such as a glass substrate. This film formation step can be conducted following a conventional method for fabricating an active matrix substrate.

[0051]

Thereafter, the transparent conductive films 37a and 37a' and the metal layers 37b and 37b' constituting the source signal line 23 and the connecting electrode 25 are sequentially formed by sputtering and are patterned into a predetermined shape.

[0052]

A photosensitive acrylic resin is applied to the resultant substrate to a thickness of 3  $\mu$ m, for example, by spin coating to form the interlayer insulating film 38. The resultant resin layer is exposed to light according to a predetermined pattern and developed with an alkaline solution. Only portions of the resin layer exposed to light are etched with the alkaline solution, forming the contact holes 26 through the interlayer insulating film 38.

[0053]

Subsequently, a transparent conductive film is formed on the resultant substrate by sputtering and is patterned to form the pixel electrodes 21. Each pixel electrode 21 is thus connected to the corresponding

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transparent conductive film 37a' which is in contact with the drain electrode 36b of the TFT 24 via the contact hole 26 formed through the interlayer insulating film 38. In this way, the active matrix substrate in Embodiment 1 is fabricated.

[0054]

The thus-fabricated active matrix substrate includes the interlayer insulating film 38 between the pixel electrode 21 and the underlying layers including the gate signal line 22 and the source signal line 23. With this interlayer insulating film, it is possible to overlap the pixel electrode 21 with the signal lines 22 and 23. As a result, when the transmission type liquid crystal display device including the thus-fabricated active matrix substrate and a counter substrate with a liquid crystal layer therebetween is completed, the aperture ratio of this device can be improved. Also, since the electric field generated at the signal lines 22 and 23 can be shielded, the disturbance in the orientation of liquid crystal can be minimized.

[0055]

The acrylic resin constituting the interlayer insulating film 38 has a dielectric constant of 3.4 to 3.5 which is lower than that of an inorganic film (the dielectric constant of silicon nitride is 8) and a high transparency. Also, since the spin coating is employed, a thickness as large as 3  $\mu\text{m}$  can be easily obtained. This reduces the capacitances between the gate signal line 22 and the pixel electrode 21 and between the source signal lines 23 and the pixel electrodes 21, lowering the signal transmittance. As a result, the influence of the

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capacitances between the signal lines 22 and 23 and the pixel electrode 21 appearing on the display, such as crosstalk, can be reduced, and thus a good and bright display can be obtained. The contact hole 26 can be formed into a sharp tapered shape by the patterning including the exposure to light and the alkaline development. This facilitates a better connection between the pixel electrode 21 and the transparent conductive film 37a'. Further, since the photosensitive acrylic resin is used, the thick film having a thickness of several micrometers can be easily formed by spin coating. No photoresist process is required at the patterning step. This is advantageous in production. Though the acrylic resin used as the interlayer insulating film 38 is colored before the coating, it can be made transparent optically by exposing the entire surface to light after the patterning step. The resin can also be made transparent chemically.

[0056]

In this embodiment, the transparent conductive film 37a' is formed as the connecting electrode 25 connecting the drain electrode 36b of each TFT 24 and the corresponding pixel electrode 21. This is advantageous in the following points. In the conventional active matrix substrate, the connecting electrode is composed of a metal layer. When such a metal connecting electrode is formed in the aperture portion, the aperture ratio is lowered. In order to overcome this problem, the connecting electrode is conventionally formed above the TFT or the drain electrode of the TFT. The contact hole is formed above the connecting electrode through the interlayer insulating film to connect the drain electrode

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of the TFT and the pixel electrode. With this conventional structure, however, when the TFT is made smaller to improve the aperture ratio, for example, it is not possible to accommodate the entire contact hole above the smaller TFT. As a result, the aperture ratio lowers. When the thickness of the interlayer insulating film is made as large as several micrometers, the contact hole should be tapered in order to connect the pixel electrode and the underlying connecting electrode, and a large-size connecting electrode is required in the TFT region. For example, when the diameter of the contact hole is 5  $\mu\text{m}$ , the size of the connecting electrode should be about 14  $\mu\text{m}$  in consideration of the tapered contact hole and the alignment allowance. In the conventional active matrix substrate, if a TFT with a size smaller than this value is realized, the oversized connecting electrode causes a new problem of lowering the aperture ratio. In contrast, in the active matrix substrate of Embodiment 1, since the connecting electrode 25 is composed of the transparent conductive film 37a', no trouble of lowering the aperture ratio arises. Further, in this embodiment, the connecting electrode 25 extends to connect the drain electrode 36b of the TFT and the electrode 25a of the storage capacitor formed by the transparent conductive film 37a'. Since the extension is also formed of the transparent conductive film 37a', it does not lower the aperture ratio, either.

[0057]

In this embodiment, the source signal line 23 is of a double-layer structure. If part of the metal layer 37b constituting the source signal line 23 is defective, the source signal line 23 can remain electri-

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cally conductive through the transparent conductive film 37a, so that the occurrence of disconnection of the source signal line can be reduced.

[0058]

(Embodiment 2)

In Embodiment 2, another method for forming the interlayer insulating film 38 will be described.

[0059]

First, a non-photosensitive organic thin film is formed by spin coating. A photoresist is then formed on the thin film and patterned. Using the patterned photoresist, the organic thin film is etched to obtain the interlayer insulating film 38 and the contact holes 26 formed through the interlayer insulating film.

[0060]

Alternatively, the non-photosensitive organic thin film may be deposited. A photoresist is then formed on the thin film and patterned. Using the patterned photoresist, the organic thin film is etched to obtain the interlayer insulating film 38.

[0061]

Using the active matrix substrate with the thus-formed interlayer insulating film 38, a transmission type liquid crystal display device with a high aperture ratio can be realized, as in the active matrix substrate in Embodiment 1.

[0062]

The non-photosensitive organic thin film used as



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the interlayer insulating film 38 in this embodiment has a low dielectric constant and a high transparency. The thickness can be as large as 3  $\mu\text{m}$ . With the low dielectric constant and the long distance between electrodes of the capacitance, the capacitances between the gate signal line 22 and the pixel electrode 21 and between the source signal line 23 and the pixel electrode 21 can be reduced.

[0063]

(Embodiment 3)

Figure 3 is a plan view of a one-pixel portion of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 3 according to the present invention. Figure 4 is a sectional view of an active matrix substrate of the transmission type liquid crystal display device taken along line B-B' of Figure 3. Components having like functions and effects are denoted by the same reference numerals as those in Figures 1 and 2, and the description thereof is omitted.

[0064]

In the active matrix substrate in Embodiment 3, the other electrode 27 of the storage capacitor facing the electrode 25a of the storage capacitor, which constitutes the end portion of the connecting electrode 25 connected to the drain electrode 36b of the TFT 24 is connected to a counter electrode formed on a counter substrate via the storage capacitor common line 6 shown in Figure 9. Each contact hole 26A through the interlayer insulating film 38 is formed above the electrode 25a and the other electrode 27 which is part of the storage capacitor common line 6. In other words, the contact hole 26A is formed above the storage capacitor

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line composed of a light-shading metal film.

[0065]

The above structure of the active matrix substrate of this embodiment has the following advantages.

[0066]

Since the thickness of the interlayer insulating film 38 is as large as 3  $\mu\text{m}$ , for example, which is well comparable with the thickness of a liquid crystal cell of 4.5  $\mu\text{m}$ , light leakage tends to occur around the contact holes 26A due to a disturbance in the orientation of the liquid crystal molecules. If the contact holes 26A are formed in the aperture portions of the transmission type liquid crystal display device, the contrast is lowered due to the light leakage. On the other hand, the active matrix substrate of this embodiment is free from this trouble because each contact hole 26A is formed above the electrode 25a and the other electrode 27 as an end portion of the storage capacitor common line 6 composed of a light-shading metal film. In other words, as long as the contact hole 26A is formed above the storage capacitor line composed of a light-shading metal film, any light leakage which may occur due to a disturbance in the orientation of the liquid crystal will not result in lowering of the contrast. This also applies to the case where the storage capacitor is formed using a portion of the adjacent gate signal line 22 as one of electrodes thereof. In this case, the contact hole 26A is formed above the light-shading adjacent gate signal line 22 and thus lowering of the contrast can be prevented.

[0067]

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In the active matrix substrate in this embodiment, the connecting electrode 25 for connecting the drain electrode 36b of the TFT 24 and the contact hole 26A is composed of the transparent conductive film 37a'. Accordingly, the aperture ratio does not become lower by forming the contact hole 26A above the storage capacitor.

[0068]

(Embodiment 4)

Figure 5 is a partial sectional view of an active matrix substrate of the transmission type liquid crystal display device of Embodiment 4 according to the present invention.

[0069]

In the active matrix substrate of Embodiment 4, each contact hole 26B is formed through the interlayer insulating film 38 above the storage capacitor common line 6. A metal nitride layer 41 is formed on the portion of the transparent conductive film 37a' under each contact hole 26B.

[0070]

The above structure of the active matrix substrate of this embodiment is advantageous in the following point.

[0071]

Some troubles arise in the adhesion between the resin used for the interlayer insulating film 38 and ITO used for the transparent conductive film or metal such as Ta and Al. For example, in the cleaning process after

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the formation of the contact hole 26B, a cleaning solvent tends to permeate from the contact hole 26B into the interface between the resin and the underlying layer, causing the resin film to peel from the transparent conductive film. In order to overcome this trouble, according to the active matrix substrate in this embodiment, the metal nitride layer 41 made of TaN, AlN, and the like which has good adhesion with the resin is formed. Accordingly, the peeling of the resin film and other troubles in the adhesion can be prevented.

[0072]

Any material can be used for the metal nitride layer 41 as long as it has good adhesion with the resin constituting the interlayer insulating film 38, the connecting electrode 37a' as the transparent conductive film, and metal such as Ta and Al. Such a material should also be electrically conductive to electrically connect the transparent conductive film 37a' and the pixel electrode 21.

[0073]

(Embodiment 5)

In Embodiment 5, a method for driving the transmission type liquid crystal display device will be described.

[0074]

In the transmission type liquid crystal display device according to the present invention, each pixel electrode overlaps the corresponding signal lines via the interlayer insulating film. If the pixel electrode does not overlap the corresponding signal lines but gaps are

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formed therebetween, regions where no electric field is applied are formed in the liquid crystal layer. This trouble can be avoided by overlapping the pixel electrode with the signal lines. The electric field also is not applied to the regions of the liquid crystal layer corresponding to the boundaries of the adjacent pixel electrodes. However, light leakage which may occur at these regions can be blocked by the existence of signal lines. This eliminates the necessity of forming a black mask on a counter substrate in consideration of an error at the lamination of the active matrix substrate and the counter substrate. This improves the aperture ratio. Also, since the electric field generated at the signal lines can be shielded, disturbances in the orientation of the liquid crystal molecules can be minimized.

[0075]

The overlap width should be set in consideration of a variation in the actual fabrication process. For embodiment, it is preferably about 1.0  $\mu\text{m}$  or more.

[0076]

Crosstalk occurs due to the capacitance between the pixel electrode and the source signal line when the pixel electrode overlaps the source signal line as described above. This lowers the display quality. In particular, in a liquid crystal panel used for a notebook type personal computer where pixels are generally arranged in a vertical stripe shape, the display is greatly influenced by the capacitance between the pixel electrode and the source signal line. This is considered to be due to the following reasons. The capacitance between the pixel electrode and the source signal line is relatively

large since, in the vertical stripe arrangement, the shape of the pixel electrode is rectangular having the side along the source signal line as the major side. Also, since the display color is different between adjacent source signal lines, there is little correlation between signals transmitted on the adjacent source signal lines. Thus, the influence of the capacitance cannot be cancelled between the adjacent source signal lines.

[0077]

According to the transmission type liquid crystal display device of the present invention, the interlayer insulating film which is composed of an organic thin film has a small dielectric constant and can be easily thicker. Therefore, the capacitances between the pixel electrodes and the lines can be reduced, as described above. In addition to this feature, the influence of the capacitance between the pixel electrode and the source signal line can be reduced to minimize vertical crosstalk which occurs in notebook type personal computers employing the following driving method.

[0078]

The method of Embodiment 5 includes driving the transmission type liquid crystal display device by inverting the polarity of the data signal every gate signal line to reduce the capacitances between the pixel electrodes and the lines (hereinafter, this method is referred to as 1H inversion driving).

[0079]

Figure 6 shows the influences of the capacitance between the pixel electrode and the source signal line

upon the charging rate of the pixel in the cases of the 1H inversion driving (Figure 7a) and a driving method where the polarity of the data signal is inverted every field (hereinafter, this method is referred to as field inversion driving) (Figure 7b).

[0080]

Figure 6 shows the ratio of the effective value of the voltage applied to the liquid crystal in the gray scale display portion when the gray scale is uniformly displayed to that when a black window pattern is displayed in the gray scale display at a vertical occupation of 33%. The X axis represents the capacitance ratio which is proportional to the variation in the voltage of the pixel electrode caused by the capacitance between the pixel electrode and the source signal line, which is represented by expression (1) below:

[0081]

$$\text{Capacitance ratio} = C_{sd} / (C_{sd} + C_{ls} + C_s) \quad \dots(1)$$

wherein  $C_{sd}$  denotes the capacitance value between the pixel electrode and the source signal line,  $C_{ls}$  denotes the capacitance value of the liquid crystal portion corresponding to each pixel at the gray scale display, and  $C_s$  denotes the capacitance value of the storage capacitor of each pixel. The gray scale display refers to the display obtained when the transmittance is 50%.

[0082]

As is observed from Figure 6, in the 1H inversion driving of Embodiment 5, the influence of the capacitance between the pixel electrode and the source signal line

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upon the effective voltage actually applied to the liquid crystal layer can be reduced to one-fifth to one-tenth of that obtained in the field inversion driving when the capacitance value is the same. This is because, in the 1H inversion driving, the polarity of the data signal is inverted at intervals sufficiently shorter than the period of one field during one field. This results in cancelling the influences of the positive signal and the negative signal on the display with each other.

[0083]

A display test was conducted using a VGA panel with a diagonal of 26 cm. From this test, it was observed that crosstalk was eminent when the charging rate difference was 0.6% or more, degrading the display quality. This is shown by the dotted curve in Figure 6. From the curve in Figure 6, it is found that the capacitance ratio should be 10% or less in order to obtain the charging rate difference of 0.6% or less.

[0084]

Figure 8 shows the relationships between the overlap amount between the pixel electrode and the source signal line and the capacitance between the pixel electrode and the source signal line when the thickness of the interlayer insulating film is used as a parameter. The VGA panel with a diagonal of 26 cm was also used in this test. In the test, the acrylic photosensitive resin (dielectric constant: 3.4) used in Embodiment 1 was used as the interlayer insulating film. In consideration of the processing precision, the overlap width between the pixel electrode and the source signal line should be at least 1  $\mu\text{m}$ . From Figures 6 and 8, it is found that the



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thickness of the interlayer insulating film should be 2.0  $\mu\text{m}$  or more to satisfy the overlap width of 1  $\mu\text{m}$  and the charging rate difference of 0.6% or less.

[0085]

Thus, according to the 1H inversion driving of this embodiment, a good display free from vertical crosstalk can be obtained without inverting the polarity of the signal on the adjacent source signal lines when the pixel electrode overlaps the source signal line. This method is therefore applicable to notebook type personal computers.

[0086]

(Embodiment 6)

In Embodiment 6, another method for driving the transmission type liquid crystal display device will be described, where the polarity of the voltage applied to the liquid crystal is inverted every gate signal line, and simultaneously the signal applied to the counter electrode is driven by alternate current in synchronization with the inversion of the polarity of the source signal.

[0087]

This driving of the counter electrode can minimize the amplitude of the source signal.

[0088]

Figure 6 also shows the curve obtained when the counter electrode is AC driven with an amplitude of 5 V. From Figure 6, it is observed that, since the 1H inversion driving is employed, the charging rate difference is

by the capacitance between the pixel electrode and the gate signal line, as well as the variation in the fabrication process, can be reduced.

[0091]

In the formation of the interlayer insulating film, the photosensitive organic material such as an acrylic resin is applied to the substrate by spin coating and patterned by light exposure and alkaline development to obtain an organic thin film with a thickness of several micrometers with high productivity. This makes it possible to fabricate the transmission type liquid crystal display device with a high aperture ratio without largely increasing production cost. The transmission type liquid crystal display device with a high aperture ratio can also be obtained by forming the organic thin film by deposition, forming a photoresist on the organic thin film, and patterning the organic thin film in an etching process. In the case where the resin used for the interlayer insulating film is colored, the resin can be made transparent by optically or chemically decoloring the resin after the patterning. As a result, a transmission type liquid crystal display device with a good color display can be obtained.

[0092]

The connecting electrode for connecting the other electrode of the TFT and the pixel electrode is formed using the transparent conductive film. This further improves the aperture ratio. The transparent conductive film can be formed simultaneously with the source signal line which is of a double-layer structure including the transparent conductive film. With the double-layer

structure, disconnection at the source signal line can be prevented.

[0093]

Each contact hole is formed through the interlayer insulating film above the storage capacitor line. This improves the contrast ratio because light leakage which may be generated due to a disturbance in the orientation of the liquid crystal can be blocked by the storage capacitor portion.

[0094]

The metal nitride layer may be formed under each contact hole formed through the interlayer insulating film. This improves the adhesion between the interlayer insulating film and the underlying film. Thus, the resultant liquid crystal display device is stable against further processing in the production process.

[0095]

Each pixel electrode may overlap the corresponding source signal line by 1  $\mu\text{m}$  or more. With this overlap, the aperture ratio, as well as the processing precision, improves. By having the thickness of the interlayer insulating film of 2.0  $\mu\text{m}$  or more, the capacitance between each pixel electrode and the corresponding source signal line can be sufficiently small even when the pixel electrode overlaps the source signal line by 1  $\mu\text{m}$  or more. As a result, a good display can be provided.

[0096]

The vertical crosstalk is further reduced by

decreasing the capacitance ratio represented by expression (1) above to 10% or less, since the capacitance between the pixel electrode and the source signal line is sufficiently reduced.

[0097]

The polarity of the data signal supplied from the source signal line may be inverted every gate signal line. This further reduces the generation of vertical crosstalk.

[0098]

The effects of the present invention can also be obtained for the active matrix substrate where the pixel electrodes are arranged in a vertical stripe shape and each pixel electrode is of a rectangular shape with the side thereof parallel to the source signal line being longer than the side thereof parallel to the gate signal line, as well as the case where each pixel electrode is of a square shape. This makes it possible to obtain a large-scale liquid crystal display device with a high aperture ratio free from vertical crosstalk for notebook type personal computers and the like.

[Brief Description of the Drawings]

[Figure 1]

A plan view of a TFT portion of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 1 according to the present invention.

[Figure 2]

A sectional view of the active matrix substrate

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of the transmission type liquid crystal display device, taken along line A-A' of Figure 1.

[Figure 3]

A plan view of a one-pixel portion of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 3 according to the present invention.

[Figure 4]

A sectional view of the active matrix substrate of the transmission type liquid crystal display device, taken along line B-B' of Figure 3.

[Figure 5]

A partial sectional view of an active matrix substrate of a transmission type liquid crystal display device of Embodiment 4 according to the present invention.

[Figure 6]

A graph illustrating the relationship between the liquid crystal charging rate difference and the capacitance ratio for transmission type liquid crystal display devices of Embodiments 5 and 6 according to the present invention and a conventional liquid crystal display device.

[Figure 7]

A view illustrating waveforms of data signals in the cases of 1H inversion driving in Embodiments 5 and 6 according to the present invention and conventional field inversion driving, respectively.

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[Figure 8]

A graph illustrating the relationship between the liquid crystal capacitance ratio and the overlap width for the transmission type liquid crystal display device of Embodiment 5 according to the present invention.

[Figure 9]

A circuit diagram illustrating a conventional liquid crystal display device having an active matrix substrate.

[Figure 10]

A sectional view of a one-pixel portion of the active matrix substrate of the conventional liquid crystal display device.

[Description of Reference Numerals]

- 6 Storage capacitor common line
- 21 Pixel electrode
- 22 Gate signal line
- 23 Source signal line
- 24 TFT
- 25 Connecting electrode
- 26, 26A, 26B Contact holes
- 31 Transparent insulating substrate
- 32 Gate electrode
- 36a Source electrode
- 36b Drain electrode
- 37a, 37a' Transparent conductive films
- 37b, 37b' Metal layers
- 38 Interlayer insulating film
- 41 Titanium nitride layer

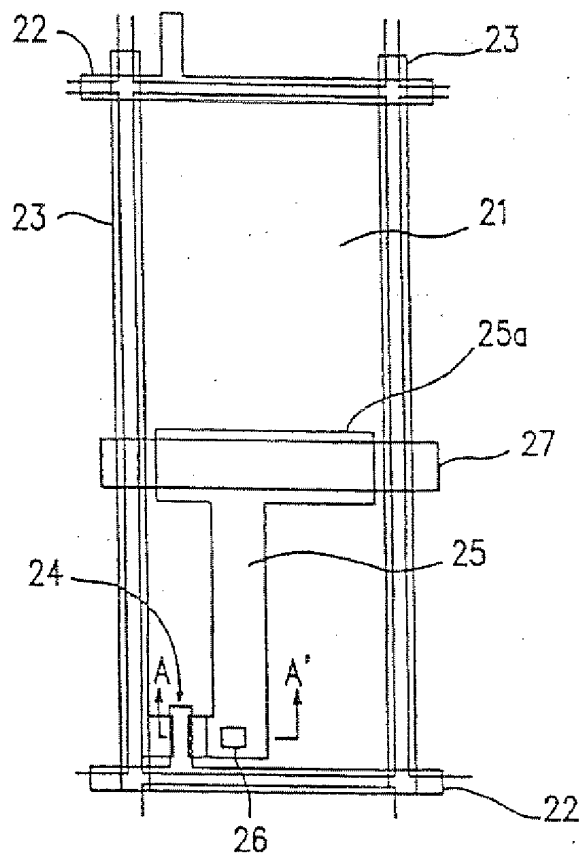
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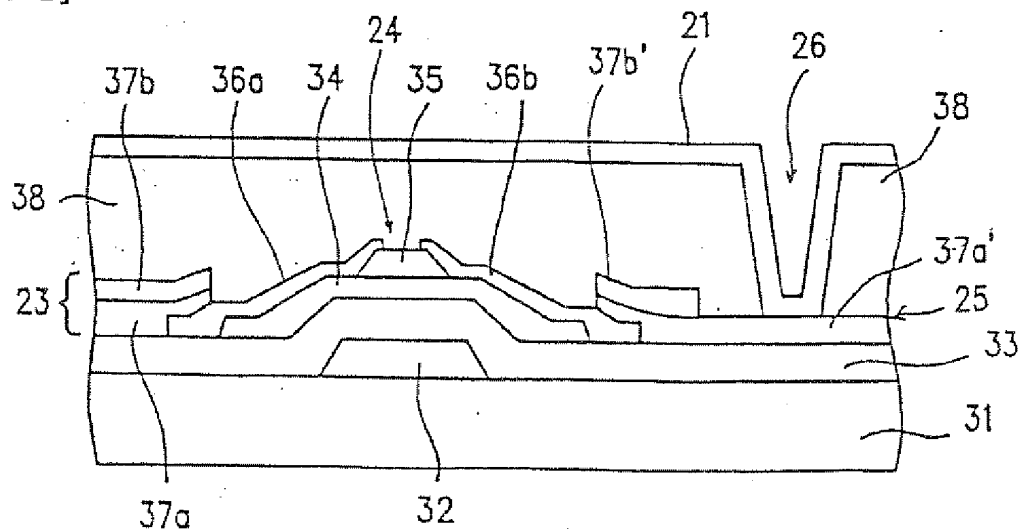
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[Name of the Document] DRAWINGS

[Fig. 1]



[Fig. 2]

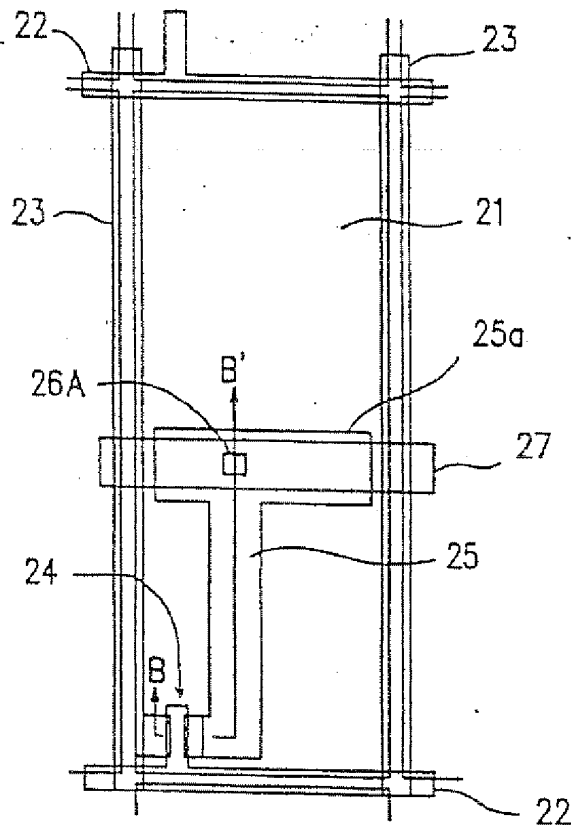


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[Fig. 3]



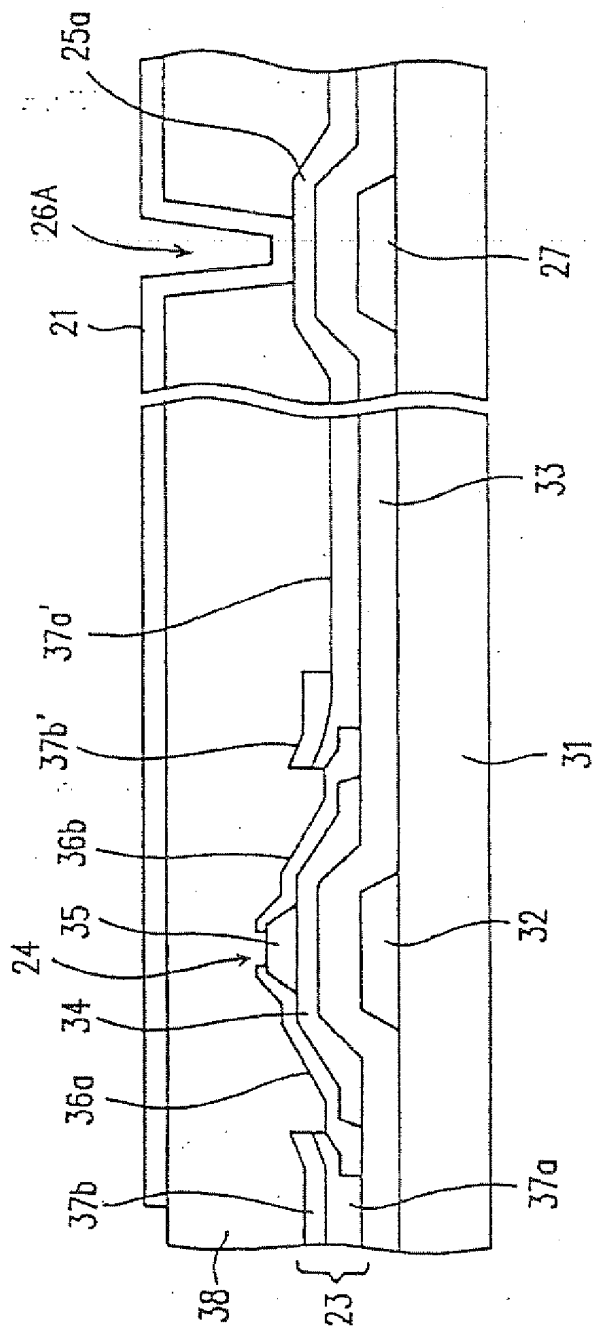


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[Fig. 4]

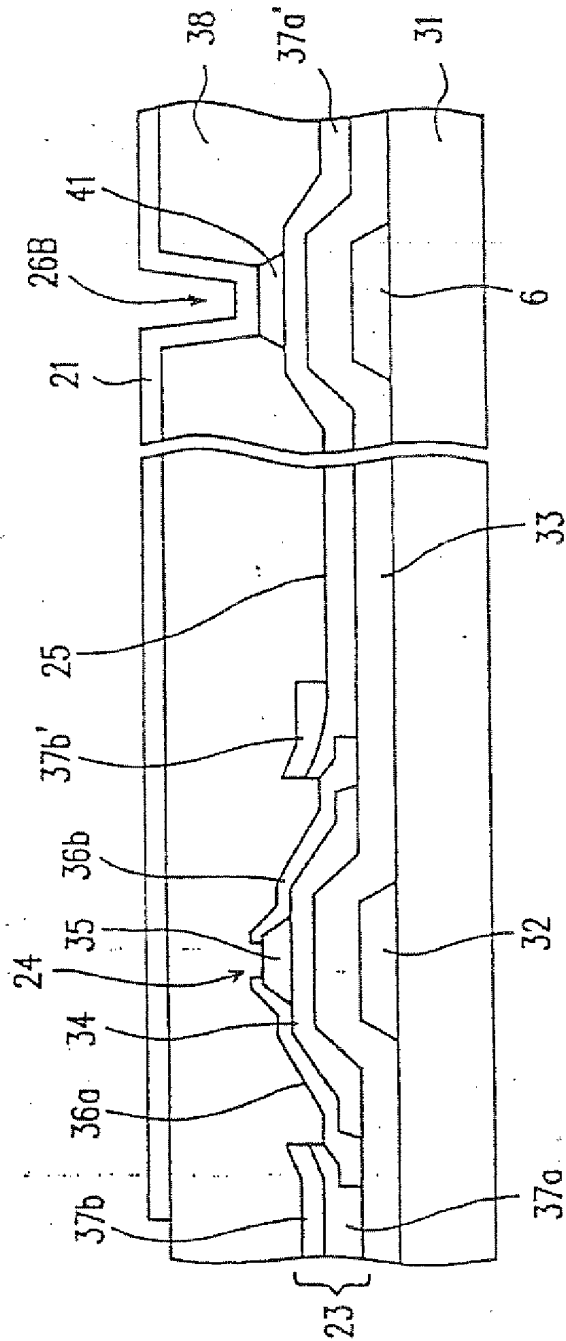


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[Fig. 5]

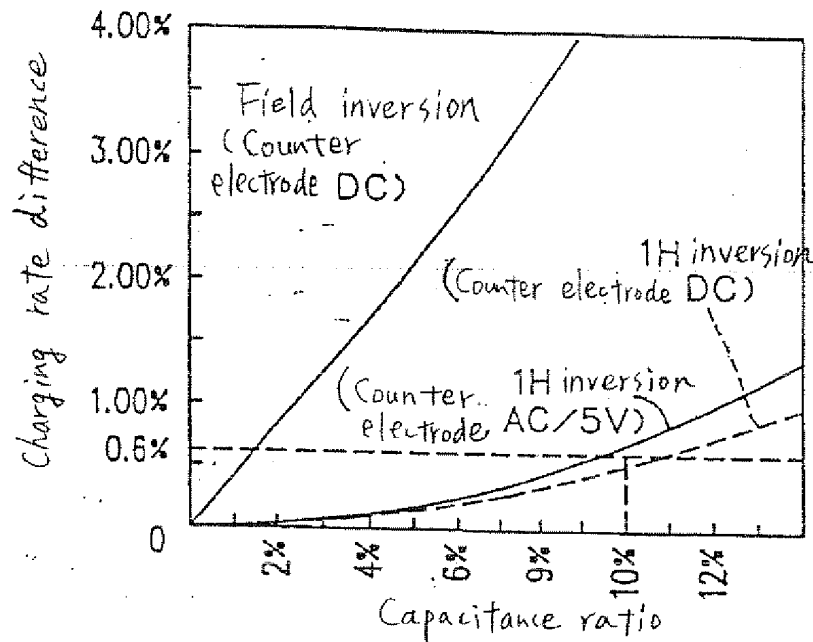


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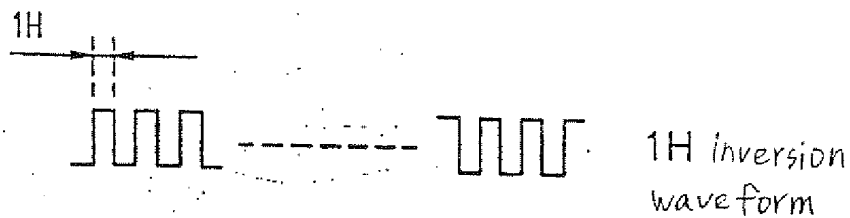
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[Fig. 6]

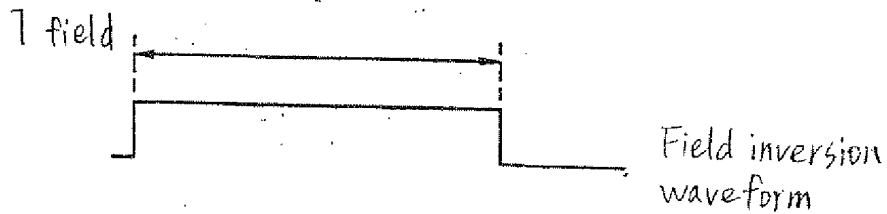


[Fig. 7]

(a)



(b)

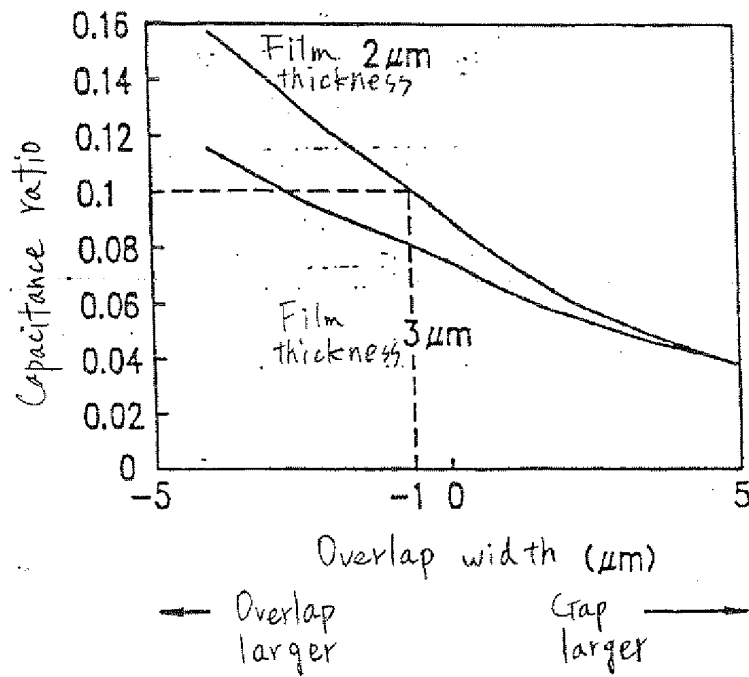


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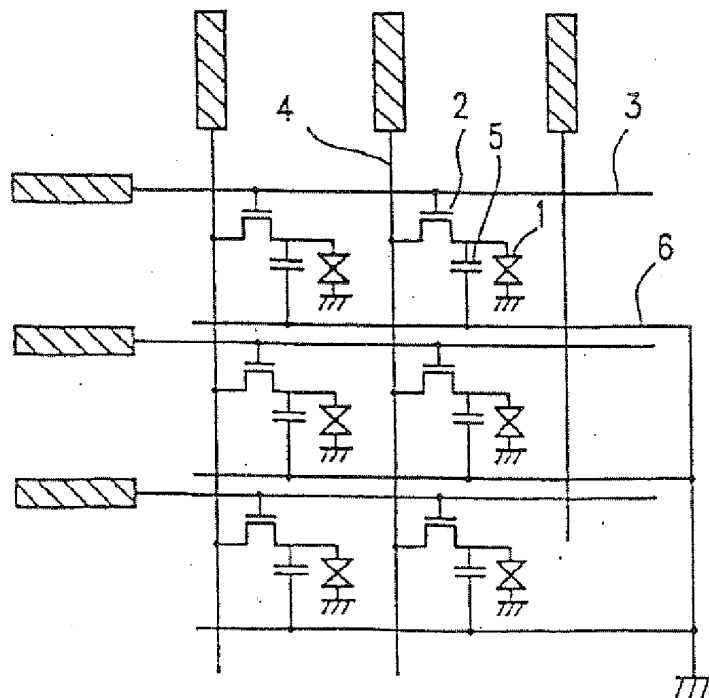
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[Fig. 8]



[Fig. 9]

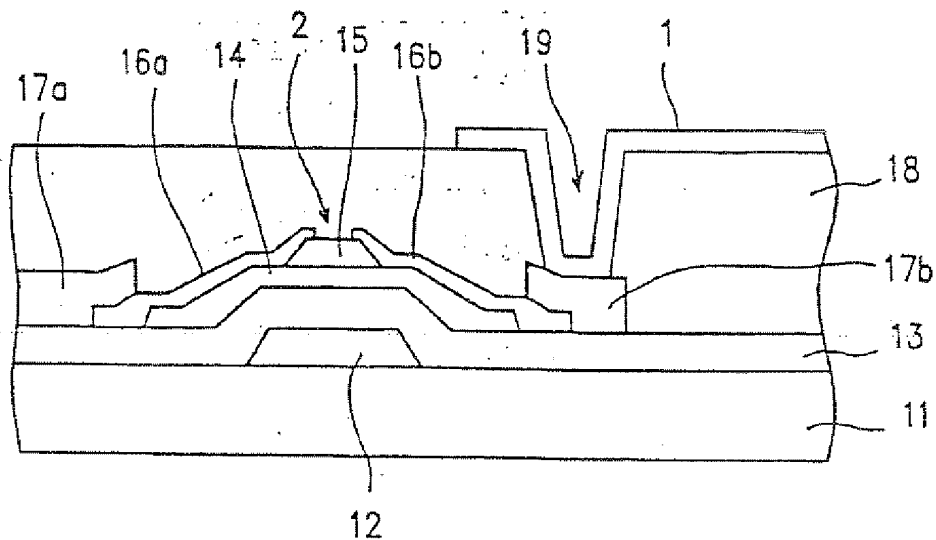


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[Fig. 10]



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[Name of the Document] ABSTRACT

[Abstract]

[Problem] Each pixel electrode overlaps corresponding signal lines to improve the aperture ratio while the influence of the capacitance between the pixel electrode and the signal lines on the display is reduced.

[Means for Solving the Problem] An interlayer insulating film 38 is formed above TFTs 24, gate signal lines, and source signal lines 23, and pixel electrodes 21 are formed on the interlayer insulating film. Each of the pixel electrodes 21 is connected to a drain electrode 36b of the TFT 24 via a connecting electrode 25 and a contact hole 26 formed through the interlayer insulating film 38. The interlayer insulating film 38 is made of an organic thin film such as a photosensitive acrylic resin and has a dielectric constant smaller than an inorganic thin film such as a silicon nitride film. The interlayer insulating film 38 can be easily thickened, to reduce the capacitance between the pixel electrode 21 and the corresponding signal lines. A transparent conductive film is used for the connecting electrode 25 connecting the drain electrode 36b of the TFT 24 and the pixel electrode 21.

[Selected Figure] Figure 2

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Applicant's Company History

Identification Number	[000005049]
1. Date of Change	August 29, 1990
[Reason for Change]	New Entry
Address	22-22, Nagaike-cho, Abeno-ku, Osaka-shi, Osaka
Name	SHARP KABUSHIKI KAISHA